Cervical spinal metastasis: anterior reconstruction and stabilization techniques after tumor resection

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Object. In a review of the literature, the authors provide an overview of various techniques that have evolved for reconstruction and stabilization after resection for metastatic disease in the subaxial cervical spine.

Methods. Reconstruction and stabilization of the cervical spine after vertebral body (VB) resection for metastatic tumor is an important goal in the surgical management of spinal metastasis. Generally, the VB defect is reconstructed with bone autograft or allograft, polymethylmethacrylate (PMMA), interbody spacers, and/or cages. In cases of PMMA-assisted reconstruction, internal devices are used to augment the fixation of PMMA. Stabilization is then achieved with anterior instrumentation, usually an anterior cervical locking plate. In some cases, posterior instrumentation may be necessary to supplement the anterior construct.

Conclusions. Anterior cervical corpectomy followed by reconstruction and stabilization is an effective strategy in the management of spinal metastases in patients.

KEY WORDS • cervical spine reconstruction • metastasis • spine tumor • corpectomy • stabilization technique

Metastatic tumors are the most common type of malignant lesions of the spine; the vertebral column is the most common site of bone metastasis. Nearly 5 to 10% of patients with systemic cancer suffer spinal metastases.[34,40] The cervical spine is the least often involved by spinal metastases (10%), followed by the lumbar spine (20%), and the thoracic spine (70%).[2] Breast, lung, prostate, and renal cell carcinomas are the most common of the tumors that metastasize to the spine. Myeloma, lymphoma, and gastrointestinal carcinoma can also invade the vertebral column.[3,10,28,34] The most common symptom is neck pain (90%); however, more than 50% of patients can present with severe deficits, including acute weakness that evolves quickly to quadriplegia. Mechanical pain secondary to instability can be severe enough that basic activities such as walking can become nearly impossible. Significant bone destruction can progress to fracture, instability, deformity, and neurological compromise. After failure of a VB to support a segment of the spinal column, effective reconstruction and stabilization are required.

Because most metastatic lesions originate in the VB, an anterior cervical corpectomy offers the most direct approach for tumor excision, neurological decompression, and effective reconstruction of the weight-bearing vertebral column.[20] This approach is especially appropriate in patients with significant VB destruction resulting in neck pain or symptomatic spinal cord compression. When choosing spinal reconstructive materials and techniques, multiple biomechanical factors must be considered to achieve anatomical restoration of sagittal and coronal plane deformity and physiological load bearing.

Stabilization and reconstruction of the cervical spine after corpectomy can be performed technically in several different ways, each with advantages and disadvantages.[5–9,15,20,25,26,32,33,35,43–45] Generally, the VB defect is reconstructed with bone autograft or allograft, PMMA, Silastic tubes, titanium interbody spacers and cages, or a combination of these. Stabilization is then achieved with anterior instrumentation, usually anterior cervical plate fixation, to prevent distraction failure and to provide increased rigidity. Additionally, posterior instrumentation with or without bone grafting may be necessary to supplement the anterior construct. In this review we discuss the various techniques of anterior VB reconstruction after corpectomy for metastatic tumors of the subaxial cervical spine.

OVERVIEW

Surgical Indications

Surgical intervention should be considered for each case of spinal metastasis. Indications for surgery include

Abbreviations used in this paper: PMMA = polymethylmethacrylate; TPS = telescopic plate spacer; VB = vertebral body.

intractable pain, spinal cord compression, and the need for stabilization of impending pathological fractures. The primary goal of surgical reconstruction and stabilization is not to cure, but rather to provide palliation of pain, preserve neurological function, and restore stability to allow early ambulation and mobilization without external orthosis.[9,14,40] These are important considerations for patients who desire comfort and ambulation during their remaining life expectancy. Consideration of surgical treatment in these patients must be weighed with respect to their overall longevity and quality of life, because the presence of a spinal lesion may accompany more disseminated cancer. Patients with a limited life expectancy from widespread and aggressive metastatic tumors that are poorly responsive to medical therapy may not benefit from major spinal reconstructive surgery. Numerous factors such as overall health, nutrition, medical comorbidities, aggressiveness of the primary cancer, and extent of preoperative neurological deficits should be weighed in the treatment decision making.

Surgical Considerations

Surgical therapy of cervical metastatic disease has undergone a gradual evolution in the last decade from primarily decompressive laminectomy to a more direct anterior approach to VB metastasis.[17,18,21,23,26,39,43] Metastatic disease most commonly involves the VB, and reconstruction after anterior corpectomy is required for stability. Tumors involving the VB of the subaxial spine can be readily approached through a standard anterior neck dissection with a transverse cervical incision. Intraoperative planning should include fiberoptic intubation, skeletal traction, and spinal cord monitoring, similar to cases of traumatic instability. Preoperative embolization with polyvinyl alcohol particles may useful for minimizing blood loss in extremely vascular tumors, such as thyroid or renal metastases.

An additional posterior approach for tumor resection and stabilization should be considered if there is evidence on neuroimaging of tumor involving three columns, significant vertebral instability, and/or marked kyphotic deformity.[26,27,44] In some cases of solitary metastasis, a combined anterior–posterior approach for a total cervical spondylectomy may be warranted.[8] Posterior stabilization is particularly important for lesions at the cervicothoracic junction because there is a higher risk of progressive kyphosis with anterior reconstruction and stabilization alone. In our practice, we prefer to use lateral mass screw/rod constructs for posterior stabilization because it is a more rigid system that does not require the structural integrity of the laminae and spinous processes. Due to the higher risk of morbidity in combined approaches, staged operations are often performed to allow a resting period for the patient. During this resting period, it is important to maximize the patient's nutritional status to optimize wound healing and recovery.

Numerous procedures have been reported for stabilization and reconstruction of the cervical spine after VB resection for tumor.[1,5–9,11,15,20,24–26,33,35,43–45] Interbody fusion with either autograft or allograft bone, or PMMA, with or without anterior plate stabilization, has been well described.[5,9,33,35,44,45] The main advantage of using bone graft for reconstruction in patients with spinal metastasis is the proven durability of the construct after fusion has occurred in patients for whom survival is expected to be longer than 6 months.[5,18,32] Although achieving a solid bone fusion would be most desirable to prevent "wearing out" of the construct, there are some disadvantages in the use of bone in these circumstances.

First, although fusion must be obtained for long-term stability, numerous factors usually work against the possibility of successful fusion in these patients, including previous or planned radiotherapy or chemotherapy and malnourishment. The ubiquity of such factors in this population results in a significant risk of pseudarthrosis and early construct failure. Second, locally recurring tumor can invade the graft and result in late failure, even if fusion is successful. Third, harvesting of iliac crest bone for grafting can result in significant postoperative pain and morbidity, further compromising the quality of life in patients with limited life expectancy. Furthermore, because bone fusion is required to establish long-term stability, the relative lack of immediate stability may result in a need for an external orthosis. For these reasons, the use of bone for reconstruction should be limited to patients who are judged oncologically to have an expected survival time of more than 6 months.[5,32]

Techniques for Reconstruction and Stabilization

Polymethylmethacrylate-Assisted Reconstruction. Use of PMMA-assisted reconstruction is a reasonable alternative to bone grafting for patients with cancer whose life expectancy is limited, because this procedure achieves immediate stabilization after radical tumor resection without the need for an external orthosis (Fig. 1).[20,22] It is most effective for spinal reconstruction if the PMMA is securely anchored to the VBs encompassing the corpectomy defect. Also, PMMA is relatively inexpensive, easy to use, and avoids donor-site complications.[7,14,15,20,30] Unlike bone graft, PMMA is unaffected by tumor invasion and appears to be safe for use in patients who subsequently undergo radiation therapy. In 1967, Scoville and coworkers[36] described the initial use of PMMA for anterior cervical stabilization in a patient with metastatic lymphoma at C4–5. Since then, various modifications of PMMA-assisted reconstruction after tumor resection have progressively evolved.[1,7,12,15,22,31,32,43]

Results of the early investigations of PMMA as a simple spacer were disappointing; there were reports of graft dislodgment.[19,31,40,41,43] Dunn[15] described a technique in which the normal VBs above and below the corpectomy defect were keyed to provide better anchorage for the PMMA (Fig. 1). Nevertheless, construct failure and graft dislodgment were observed in patients who were treated with this technique.[15,37,38] This prompted a search for better methods to augment fixation of PMMA to the adjacent VBs, with a variety of materials, including Steinmann pins (Fig. 2 *upper*), internal screws (Fig. 2 *lower*), and Kirschner wires[1,4,12,42,43] being investigated.

Sundaresan, et al.,[43] performed reconstruction with PMMA and Steinmann pins in 101 patients with vertebral metastasis. After the corpectomy, Steinmann pins are placed into the VBs above and below the level of the resection and PMMA is poured into the resection cavity

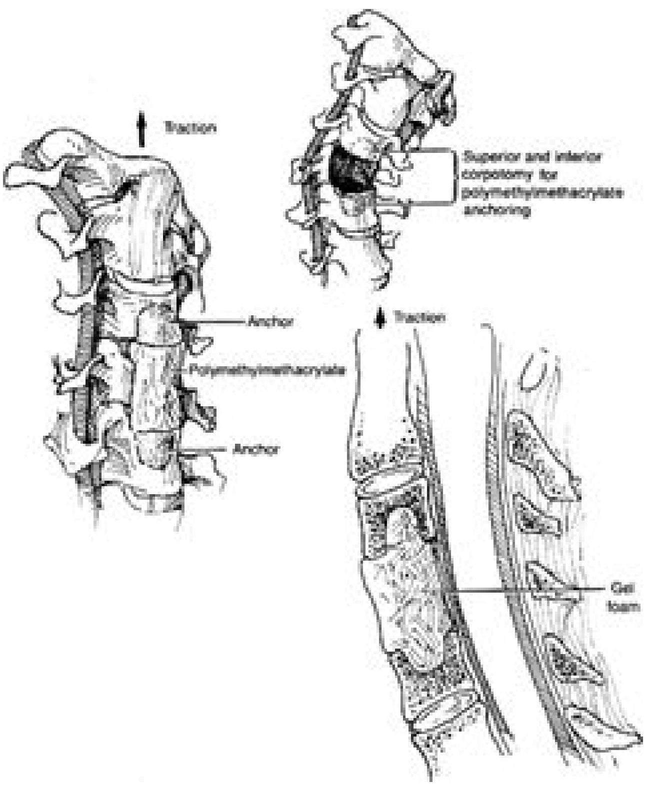

Fig. 1. Drawings showing anterior reconstruction of spinal defects with PMMA. The VBs above and below the corpectomy defect are keyed to provide better anchorage for the PMMA. Reprinted with permission from Dunn EJ, Ono K, Fellrath RF Jr: Diagnosis and management of cervical spine tumors, in Sherk HH (ed): **The Cervical Spine: An Atlas of Surgical Procedures.** Philadelphia: Lippincott Williams & Wilkins, 1994, pp 251–287.

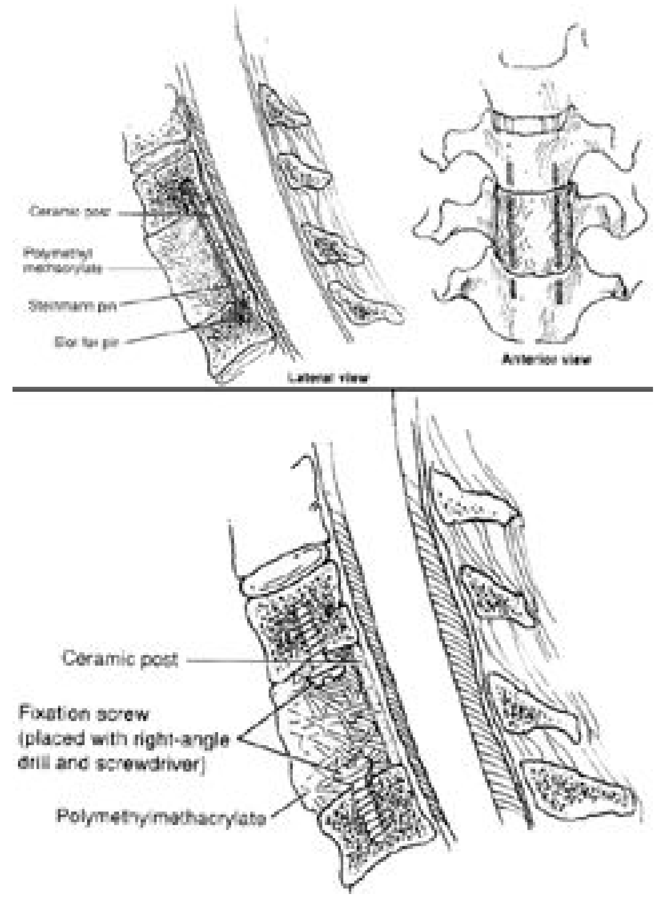

Fig. 2. Drawings showing anterior reconstruction with PMMA and Steinmann pins *(upper)* and internal screws *(lower)*. Reprinted with permission from Dunn EJ, Ono K, Fellrath RF Jr: Diagnosis and management of cervical spine tumors, in Sherk HH (ed): **The Cervical Spine: An Atlas of Surgical Procedures.** Philadelphia: Lippincott Williams & Wilkins, 1994, pp 251–287.

(Fig. 2 *upper*). Gelfoam or fat is placed over the dura to protect against thermal injury from the exothermic polymerization reaction, and saline irrigation is used to dissipate the heat of polymerization. Pain relief was obtained in 85% of patients, and the overall ambulation rate increased from 55 to 78% postoperatively. On the other hand, complications of construct failure and devastating dislodgment of pins resulting in esophageal perforation and spinal cord injury continued to be reported.[6,31,43]

Thus, the use of various hook and rod systems were advocated to reduce the rate of dislodgment. Harrington[20–22] described the use of distraction rods (Harrington or Knodt rods) and sacral hooks to augment fixation with PMMA and to restore VB height (Fig. 3). The Knodt rods come in 4- to 10-cm lengths and can be used for reconstruction of multiple VBs.[21] The endplates of the corpectomy cavity are prepared with a high-speed drill and fashioned to accept both the rod and hook. By turning the distraction rod, the hooks are progressively anchored into the desired positions in relation to the spine. The PMMA is then placed in the corpectomy defect and packed firmly around the endplate. Despite some success, however, construct failures and graft dislodgment resulting in esophageal obstruction continued to be reported.[20]

Cervical Prosthesis/PMMA Constructs. Perrin and McBroom[34] described a method for PMMA interposition incorporated about a fixation device that bridges the corpectomy defect. A U-shaped stainless steel reconstruction plate (Wellesley wedge) with 2-mm guide holes is contoured to fit the corpectomy defect (Fig. 4 *left*). Screws are used to secure the plate into the VBs above and below the corpectomy, providing axial and rotational stability. The PMMA is then molded into the defect and placed around the plate to provide axial strength and support. The plate contour prevents posterior displacement of the construct into the spinal canal; however, anterior displacement has been reported.[34]

Ono and coworkers[33] described the use of a ceramic prosthesis used in conjunction with PMMA to augment fixation (Fig. 4 *right*). This device contains portals anteriorly, superiorly, and inferiorly. After corpectomy, anchor holes are created within the superior and inferior endplates to allow PMMA fixation. The prosthesis is then introduced into the defect and PMMA is poured into the anterior portal of the device. Because there is no posterior portal, the spinal cord is protected during PMMA polymerization. The PMMA fills the superior and inferior portals, allowing fixation in the anchor holes. The ridge at the superior and inferior ends of the prosthesis prevents dis-

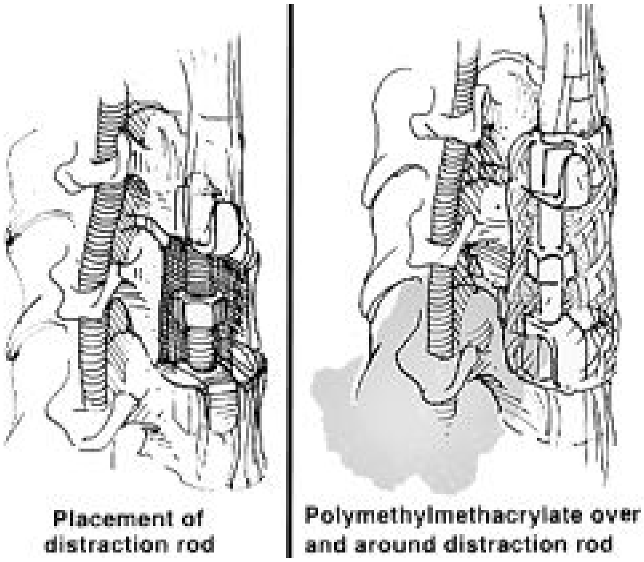

Fig. 3. Drawings showing reconstruction with a Knodt distraction rod and hooks to provide fixation for PMMA and to restore VB height. Reprinted with permission from Dunn EJ, Ono K, Fellrath RF Jr: Diagnosis and management of cervical spine tumors, in Sherk HH (ed): **The Cervical Spine: An Atlas of Surgical Procedures.** Philadelphia: Lippincott Williams & Wilkins, 1994, pp 251–287.

lodgment posteriorly into the spinal canal. In 18 patients who were treated with this technique, 94.1% experienced pain relief, 91.7% recovered from a preoperative motor deficit, and 87.5% became ambulatory after surgery.

Anterior Cervical Plate Stabilization. The addition of an anterior cervical locking plate and screws in conjunction with PMMA-assisted reconstruction for spinal metastasis has dramatically reduced the rate of construct failure.[32] Caspar, et al.,[5] reported on 30 patients who underwent placement of an anterior cervical plate after corpectomy for cervical spinal neoplasms. In that series, patients achieved long-term or lifelong mechanical stability without hardware-related complications. Anterior cervical plating offers the advantages of immediate rigid stability and restoration of normal lordosis. For patients with longer life expectancy who receive bone graft for reconstruction, use of anterior cervical plates appears to enhance solid bone fusion.[5] The reduced rate of construct failure can be attributed to load sharing and preventing distraction failure.

Coaxial Double-Lumen PMMA Reconstruction. More recently, coaxial double-lumen PMMA reconstruction (the "chest tube technique") has become popular (Fig. 5).[10,16,32] This technique, which involves keyholing chest tubes into the adjacent VBs and impregnating them with PMMA, has been described as yielding excellent clinical

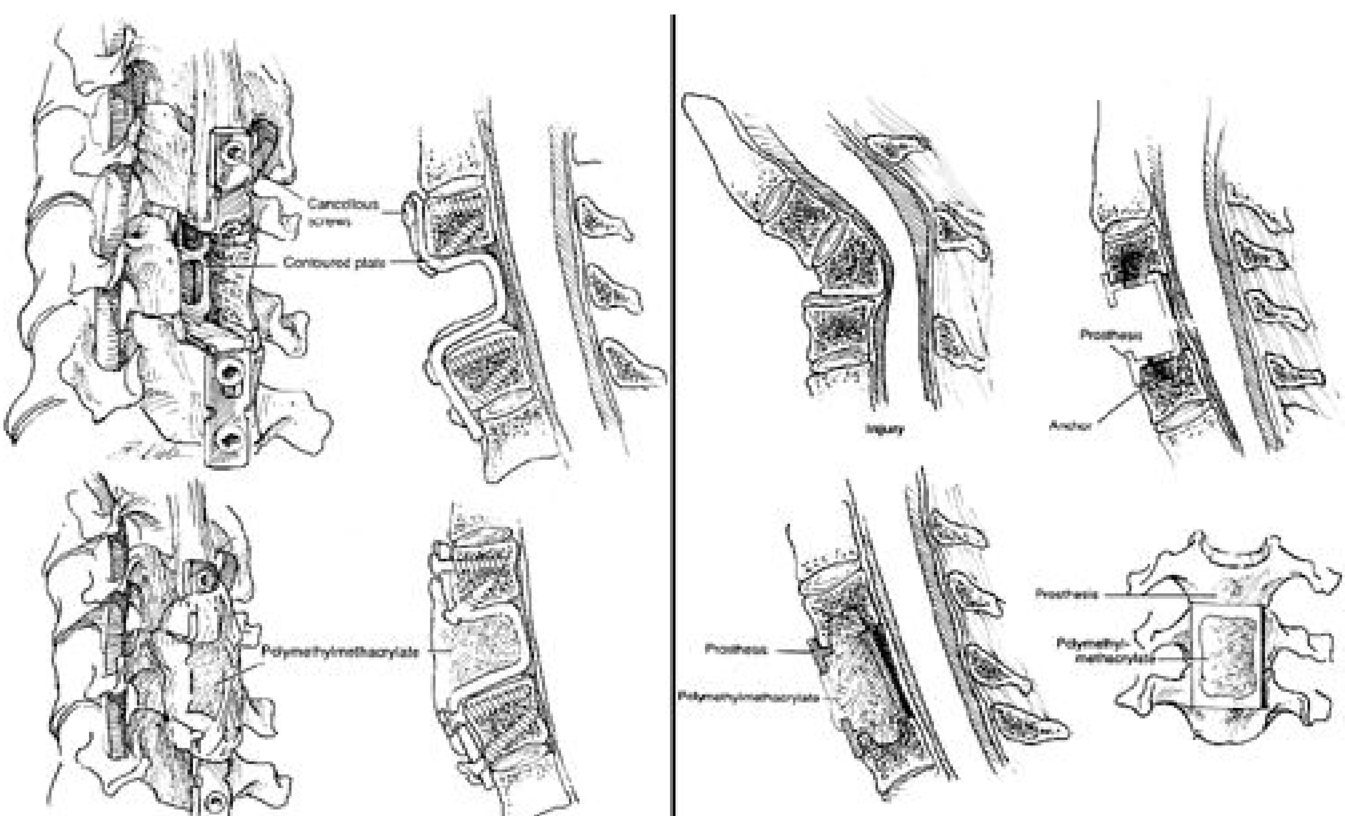

Fig. 4. *Left:* Drawings showing reconstruction and stabilization with PMMA incorporated within a U-shaped plate fixation device (Wellesley wedge). *Right:* Drawings showing PMMA reconstruction with an interbody ceramic prosthesis. Reprinted with permission from Sherk HH (ed): **The Cervical Spine: An Atlas of Surgical Procedures.** Philadelphia: Lippincott-Raven, 1994, pp 251–287.

Fig. 5. Drawing showing coaxial double-lumen PMMA reconstruction with Silastic tubes. Reprinted with permission from Miller DJ, et al: Coaxial double-lumen methylmethacrylate reconstruction in the anterior cervical and upper thoracic spine after tumor resection. **J Neurosurg (Spine 2) 92:**181–190, 2000.

results, particularly when combined with anterior plating and/or posterior instrumentation as needed. This method has the advantage of providing a barrier between the PMMA cement and the adjacent dura, thus protecting the neural elements from direct thermal injury during the exothermic solidification of PMMA. It also prevents compression of the neural elements during PMMA expansion.

Miller and coworkers[32] described a technique in which PMMA is injected through a coaxial, double-lumen chest tube inserted in the corpectomy defect (Fig. 5). A No. 28 French chest tube (inner chest tube) is cut to a length that spans the defect, and a small hole is made in the center to allow administration of PMMA into the tube. Small notches are also made at both ends of the tube to allow extrusion of PMMA to maximize cement–bone contact. Next, a 1-cm-wide strip is removed longitudinally from a No. 40 French chest tube (outer tube) and the modified apparatus is placed between the inner chest tube filled with PMMA and the dura. This outer chest tube serves as a trough that catches the material that has extruded and spilled over from the inner chest tube during PMMA injection. When the PMMA has polymerized to a viscid consistency, the outer chest tube is removed. Once the PMMA has hardened completely, manual distraction of the cervical spine is released, allowing compression to ensue. An anterior cervical plate stabilization system is placed to prevent distraction failure.

Titanium Mesh Interbody Cage/PMMA Reconstruction. The titanium mesh cage is a cylindrical interbody reconstruction device that is available in several shapes, configurations, and diameters.[13,29] It can easily be trimmed and custom fit to the vertebrectomy defect (Fig. 6). The inside of the cage can be filled with autograft or allograft if bone fusion is desired. For most patients with cancer, we prefer to fill the cage with PMMA to achieve immediate stability; this increases the surface area between the vertebral endplates and the titanium mesh cage. To prevent PMMA leakage through the mesh interstices, we place an incised chest tube around the mesh cage before implantation. This also prevents the complication of thermal injury to the spinal cord. The final construct is then augmented with anterior cervical plate fixation.

Telescopic Plate Spacer. The TPS (Interpore Cross International, Irvine, CA) is a new option for spine surgeons confronted with the technical dilemma of how to reconstruct a cervical corpectomy defect after tumor surgery.[11] This device is a titanium, cervical plate–interbody spacer hybrid, which can be used in either one- or two-level corpectomy defects (Fig. 7). The spacer portion of the device is placed into the defect with the set screw facing anteriorly. The device is opened until it fits snugly within the defect and maximal correction of kyphosis has been achieved. The set screw is then tightened to lock the spacer portion of the device permanently at the desired height. This portion is hollow and may be packed with bone graft, if desired. The plate portion of the device is then fixed to the adjacent VBs with bone screws in a manner similar to most standard anterior cervical plates. Thus, through its telescoping effect, the device can be expanded to fit corpectomy defects and to restore anterior column height and correct kyphotic deformity.

In a prospective study by Coumans, et al.,[11] 15 patients underwent placement of the TPS filled with allograft bone. Nine of these patients, who where still alive at 12 months, demonstrated bone fusion on computerized tomography scans. There were no instrumentation failures or neurological complications.

Fig. 6. Neuroimages demonstrating reconstruction after C-4 corpectomy for a renal cell metastasis; stabilization was achieved using a titanium mesh interbody cage and chest tube construct filled with PMMA, supplemented by an anterior cervical plate. *Left:* Preoperative T_2-weighted magnetic resonance image, sagittal view, revealing VB collapse at C-4. *Right:* Postoperative cervical x-ray film, lateral view.

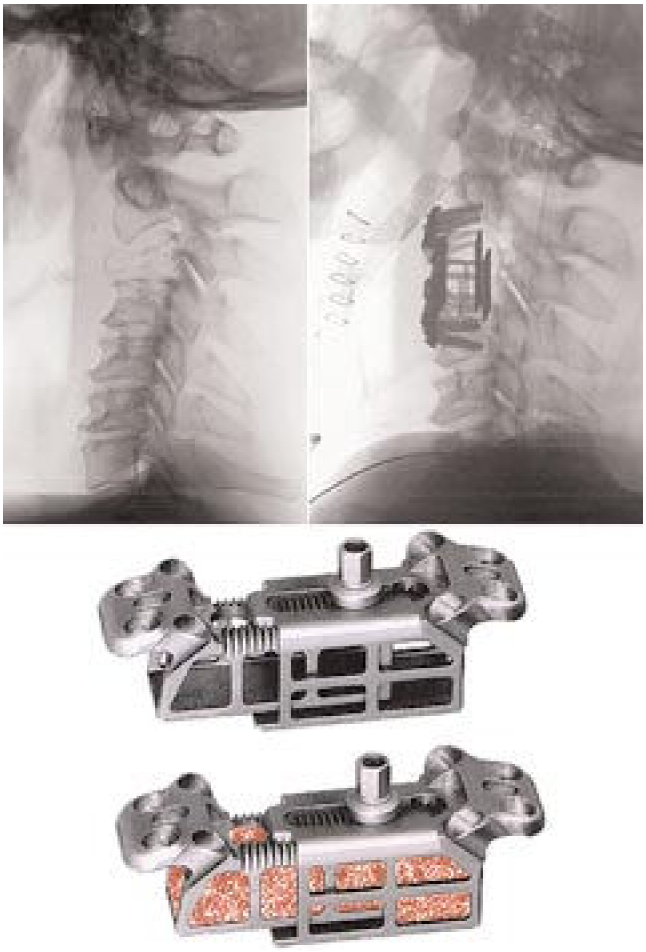

Fig. 7. Squamous cell carcinoma of the lung metastatic to C-3. *Upper Left:* Preoperative plain x-ray film showing marked destruction of the C-3 VB and associated kyphotic deformity. *Upper Right:* Postoperative x-ray film showing placement of the TPS device into the C-3 corpectomy defect, restoring anterior column height. *Lower:* Illustrations of the TPS device. The apparatus is expandable to fit the size of the corpectomy defect and can be filled with bone autograft if desired. Reproduced with permission from Interpore Cross International, Irvine, California.

The TPS system provides immediate stabilization and allows for early mobilization, obviating the need for external orthosis. This device also obviates the need for PMMA, thus eliminating the risk of thermal injury to the spinal cord. The ease of implantation of the TPS may also aid surgeons who are not often confronted with this surgical dilemma. If additional stability is required, supplementary posterior stabilization may be indicated. Currently, the TPS device is used under institutional review board supervision and is approved by the Food and Drug Administration solely for humanitarian use in patients with metastatic spine disease.

CONCLUSIONS

Anterior cervical corpectomy followed by reconstruction and stabilization is an effective strategy in the management of spinal metastasis in some patients. Various techniques that are available in the armamentarium of the spine surgeon are presented in this overview. In patients with a limited life expectancy, reconstruction with PMMA achieves immediate stability, obviating the need for an external orthosis and allowing for early mobilization. The addition of anterior cervical plate fixation provides extra support to prevent distraction failure. In some cases, posterior reconstruction may also be necessary to achieve adequate stability.

Disclaimer

The authors have no financial interest in the TPS system or in the company that manufactures it.

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